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STANDARDIZED CATCH RATES IN BIOMASS FOR THE SOUTH ATLANTIC STOCK OF SWORDFISH (*XIPHIAS GLADIUS*) FROM THE SPANISH LONGLINE FLEET FOR THE PERIOD 1989-2011

A. Ramos-Cartelle[1], B. García-Cortés[1] and J. Mejuto[1]

SUMMARY

Standardized catch rates in number and biomass were updated using General Linear Modeling (GLM) procedures from trips carried out by the Spanish surface longline fleet fishing the South Atlantic swordfish stock during a period of 23 years (1989-2011). Nominal catch rates were also updated for the same period. The criteria used to define factors such as area, time periods, gear, bait, fishing strategy and models were similar to those used in previous papers. The final models explained 65% and 71% of the CPUE variability in number and weight, respectively. The statistical diagnoses were highly satisfactory. The results point to very stable standardized CPUE and mean weight trends over time.

RÉSUMÉ

Les taux de capture standardisés en nombre et en biomasse ont été actualisés à l'aide de procédures de modèle linéaire généralisé (GLM) à partir de sorties réalisées par la flottille palangrière de surface espagnole qui pêchait le stock d'espadon de l'Atlantique Sud pendant une période de 23 ans (1989-2011). Les taux de capture nominale ont également été actualisés pour la même période. Les critères utilisés pour définir des facteurs, tels que zones, périodes temporelles, engin, appât, stratégie de pêche et modèles, étaient similaires à ceux utilisés dans des documents antérieurs. Les modèles finaux ont expliqué 65% et 71% de la variabilité de la CPUE en nombre et en poids, respectivement. Les diagnostics statistiques ont été hautement satisfaisants. Les résultats indiquent des tendances très stables de la CPUE standardisée et du poids moyen dans le temps.

RESUMEN

Se actualizan tasas de captura normalizadas usando técnicas de Modelo Lineal Generalizado (GLM) a partir de mareas realizadas por la flota española de palangre de superficie sobre el stock de pez espada del Atlántico Sur, durante un periodo de 23 años entre 1989 y 2011. Además se obtuvieron tasas de captura nominal de pez espada para el mismo período. Los criterios usados para la definición de las áreas consideradas, los periodos temporales, los factores de arte y cebo, la estrategia pesquera y los modelos fueron similares a los empleados en documentos anteriores. El modelo usado explicó el 65% y 71% de la variabilidad de la CPUE en número y peso, respectivamente. Los diagnósticos estadísticos resultaron altamente satisfactorios. Los resultados sugieren tendencias estables de la CPUE y del peso medio estandarizado a lo largo de la serie analizada.

KEY WORDS

Swordfish, CPUE, GLM, longline

1. Introduction

Catch per unit of effort data from commercial fleets have been used in the assessment of tuna and tuna-like species as indices of the relative abundance in a great number of fisheries. The Generalized Linear Modeling technique (GLM) (Robson 1966, Gavaris 1980, Kimura, 1981) was used as a routine instrument in the estimation of standardized catch rates based on data from commercial longline fleets.

[1] Instituto Español de Oceanografía. P.O. Box 130, 15080 A Coruña. Spain; tunidos.corunha@co.ieo.es; http://www.co.ieo.es/tunidos

The activity of the Spanish surface longline vessels targeting swordfish in the South Atlantic started in the mid-1980s when some boats with frozen systems crossed the stock boundary line defined by ICCAT at 5º North latitude. The traditional multifilament surface longline gear used by the Spanish fleet has remained relatively constant over historical decades in terms of general structure and configuration (Rey *et al*. 1988, Hoey *et al*. 1988). However, important changes in the fishing strategy and the introduction of a new surface longline style have been observed and described for recent periods (Mejuto *et al*. 1997, 1998, 1999, 2000, 2001, 2002, Mejuto and De la Serna 1995, 1997, 2000, García-Cortés *et al*. in press). The multifilament style, traditionally used by the Spanish longline fleet, was replaced by the imported monofilament type (American style) in most of the vessels from the end of the last century and remains as preferential gear. The targeting criterion of this fleet was traditionally focused on swordfish, but this strategy has become a combination of swordfish and blue shark as the main and valuable species during the most recent periods. The impact of some of these changes on the fishing strategy of the Spanish fleet has already been considered in recent papers and compared with the results obtained using traditional approaches (Mejuto and De la Serna 2000, Mejuto *et al*. 2000, 2011, García-Cortés *et al*. 2010, in press).

2. Material and methods

The trip records used were voluntarily provided by the Spanish surface longline fleet targeting swordfish in the South Atlantic stock during 1989-2011. The standardized CPUE in number of fish caught and biomass (kg round weight) for a period of 23 years (1989-2011) was performed using GLM procedures (*SAS 9.2 ver*.) assuming a log-normal distribution of catch rates: LOG (CPUE) = u + Y + Q + A + R + G + B+ A*Q + e. Where: u = overall mean, Y= effect year, Q =effect time (quarters), A =effect area, R= effect 'Ratio', G= effect gear style, B= bait type, e = logarithm of the normally distributed error term. The two levels of gear type were defined: 1= traditional multifilament main line and 3= new monofilament style. Three levels of bait types were considered: 1= mackerel, 6= squid and 9= other types or combinations. The temporal definition corresponding to "quarters" was as follows: Q1 = January, February, March; Q2 = April, May, June; Q3 = July, August, September; Q4 = October, November and December. The variable 'ratio' was defined for each available trip record as the percentage of swordfish in weight related to the swordfish and blue shark combined and was categorized into ten 'ratio' categories of 10% intervals in order to classify the criteria of the skipper regarding the two potentially desirable main species (Mejuto and De la Serna 2000, Mejuto *et al.* 2000, 2001, 2002, 2010). The standardized mean weight of swordfish per year and their confidence intervals were also obtained using GLM. The overall nominal CPUE in weight per thousand hooks was obtained for the same period using task II data. Both, nominal and standardized CPUE (in kg round weight) were scaled to their maximum values for comparison. The hypothetical boundary line between Atlantic stocks was kept at 5ºN latitude as assumed by the ICCAT. The final runs were done considering 5 areas (**Figure 1**). The methods and specifications were consistent with previous analyses (Mejuto *et al.* 2000, 2001, 2010).

3. Results and discussion

Figure 1 shows the spatial coverage of the fishing effort of the observations taken from the South Atlantic Ocean for the combined period 1989-2011, as well as of the areas defined for the GLM runs. A total number of 6,316 observations were available for the whole period. In general the number of spatial-temporal observations may be considered satisfactory (84% of the total squares between 5ºN-40ºS and 20ºE-60ºW were covered). However, some spatial-temporal cells were scarcely represented at the beginning of the time series due to the progressive geographical entry and expansion of these fleets from intertropical areas towards other regions of the South Atlantic.

Table 1 provides a summary of the ANOVA results from GLM procedures. The significant defined models explained 65% and 71% of the CPUE variability in number and weight, respectively. Most of the CPUE variability (Type III SS) may be attributed to the variable ratio and secondly to the gear style factor as would be expected and observed from previous results from North and South Atlantic analyses belonging to different fleets. The gear style was one of the most important factors explaining the CPUE variability because the effort is expressed in relation to the number of hooks. Other factors considered, such as year or area, were also significant and quite important. The year and area factors seem to be qualitatively different in terms of explaining the variability of the CPUE in number or weight. Frequency distribution of the standardized residuals, years combined, shows a normally-distributed shape. The distribution of the residuals per year and qq-plots were highly satisfactory (**Figure 2**). **Table 2** provides information on estimated parameters, their standard error, CV (%), relative CPUE and upper and lower 95% confidence limits, in number and in biomass.

The standardized CPUEs obtained per year as well as the standardized mean weight and their respective confidence intervals, were also plotted (**Figure 3**). The analysis shows an overall stable trend of the CPUE in both number and weight and almost identical in trend during the whole 23 year period observed. Important multi-annual phases in the standardized mean weights were not initially detected.

The highest nominal catch rates were obtained during the most recent period after 1999 when the monofilament American longline style gear was introduced by most of the boats. The scaled overall nominal catch rates and scaled standardized CPUE of swordfish per year (in kg round weight) are compared in **Figure 4**.

The standardized CPUE obtained for the analyzed period suggest moderate and biologically plausible changes in the relative biomass index between couples of consecutive years ($CPUE_{yr+1}$ vs. $CPUE_{yr}$) with a mean value of the biannual increases of 8.95% (CI95%= ± 2.84%) when the absolute increments are considered and -1.09% (CI95%: ± 4.74%) when the balance between positive and negative increments are averaged, respectively. Moderate increments in number of fish between couples of consecutive years were also obtained with a mean value of 9.16% (CI95%= ± 3.44) when the absolute increments are considered and -0.37% (CI95%: ± 5.25%) when the balance between positive and negative increases are averaged, respectively.

Periodical fluctuations in both CPUE indices suggest phases of around 5 years in the abundance -or availability- in the number of fish, which also resulted in similar phases of the biomass index observed. The response of the South Atlantic Ocean to El Niño-Southern Oscillation (Colberg *et al.* 2004) and tele-connected events affecting the South Atlantic swordfish should not be ruled out. The SST anomalies suggested to some authors the possible influence of major ENSO events on the South Atlantic and also the lack or lesser influence of minor ENSO events. These oscillations occur on a relatively short inter-annual mean timescale of around a 4-year period (Venegas *et al.* 1997). A large number of descriptions suggest that ENSO episodes trigger large-scale changes in the tropical Atlantic areas. The SST fluctuation in the tropical sectors of this ocean is within the range of 4 to7 years as for the Southern Oscillation index (SOI) and warming is apparent in the South Atlantic areas during ENSO years (Nicholson 1997). The Brazil Current plays a key role in these areas because it runs South along the coast of Brazil from 9ºS to about 40ºS affecting the upper 600m of the water column. So the impact on the drifting and expansion of the warm water mass affecting the most active areas of reproduction of the swordfish could be very important. Quasi-yearly or short-term temperature anomalies of warm-cold fronts occur and they would seem to be related to the El Nino-Southern Oscillation (ENSO) events, also detected from the short term phases of the multivariate ENSO index (MEI). Anomalous cold water extensions to the north occur on the shelf generally one year after every warm ENSO event, and anomalous warm water extensions generally take place one year after every cold ENSO (Lentini *et al.* 2001).

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References

Colberg, F., Reason, C.J.C. and Rodgers, K. 2004. South Atlantic response to El Niño-Southern Oscillation induced climate variability in an ocean general circulation model. Journal of Geophysical Research, 109, nº C12:1-14.

García-Cortés, B., Mejuto J., de la Serna, J. M. and Ramos-Cartelle, A. 2010. A summary on the activity of the Spanish surface longline fleet catching swordfish (*Xiphias gladius*) during the years 2006-2007. Collect. Vol. Sci. Pap. ICCAT, 65(1): 135-146.

García-Cortés, B., Ramos-Cartelle, A. and Mejuto, J. in press. Standardized catch rates in biomass for North Atlantic stock of swordfish (*Xiphias gladius*) from the Spanish surface longline fleet for the period 1986-2011. Collect. Vol. Sci. Pap. ICCAT, (SCRS/2013/105).

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37: 2272-2275.

Hoey, J., Mejuto, J., Iglesias, S. and Conser R.J. 1988. A comparative study of the United States and Spanish longline fleet targeting swordfish in the Atlantic Ocean, north of 40º latitude. Collect. Vol. Sci. Pap. ICCAT, 27: 230-239.

Kimura, D. K. 1981. Standardized measures of relative abundance based on modelling log (CPUE) and their application to Pacific Ocean Perch. J. Cons. Int. Explor. Mer. 39: 211-218.

Lentini, C.A.D., Podesta, G.G., Campos, E.J.D. and Olson, D.B. 2001. Sea surface temperature anomalies on the Western South Atlantic from 1982-1994. Continental Shelf Research, 21: 89-112.

Mejuto, J., García, B. and De la Serna J.M. 1997. Activity of the Spanish surface longline fleet catching swordfish (*Xiphias gladius*) in the Atlantic, years 1994 and 1995. Collect Vol. Sci. Pap. ICCAT, 46(3):308-310.

Mejuto, J., García, B, and De la Serna, J.M. 1999. Activity of the Spanish surface longline fleet catching swordfish (*Xiphias gladius*) in the Atlantic in the year 1997. Collect Vol. Sci. Pap. ICCAT, 49(1):428-438.

Mejuto, J., García, B. and De la Serna, J.M. 2000. Preliminary standardized catch rates, in biomass, for the swordfish (*Xiphias gladius*) caught by the Spanish longline fleet in the South Atlantic stock, for the period 1989-1998. Collect Vol. Sci. Pap. ICCAT, 51(4):1293-1311.

Mejuto, J. and De la Serna, J.M. 2000. Standardized catch rates by age and biomass for the North Atlantic swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1983-1998 and bias produced by changes in the fishing strategy. Collect Vol. Sci. Pap. ICCAT, 51(5):1387-1410.

Mejuto, J., De la Serna, J.M., and García, B. 1998. Updated standardized catch rates by age, sexes combined, for the swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, for the period 1983-1996. Collect Vol. Sci. Pap. ICCAT, 48(1):216-222.

Mejuto, J., García, B. and De la Serna, J.M. 2001. Standardized catch rates for the North and South Atlantic swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1983-1999. Collect Vol. Sci. Pap. ICCAT, 52(4):1264-1274.

Mejuto, J., García, B. and De la Serna, J.M. 2002. A note on preliminary standardized catch rates for the North Atlantic swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1983-2000. Collect Vol. Sci. Pap. ICCAT, 54(5):1550-1554.

Mejuto, J., García-Cortés B. and Ramos-Cartelle, A. 2010. Standardized catch rates for the South Atlantic stock of swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1989-2008. Collect. Vol. Sci. Pap. ICCAT, 65(1): 285-294.

Mejuto, J., Ortiz de Urbina, J., Ramos-Cartelle, A. and García-Cortés, B. 2011. Equivalence in efficiency per hook between the traditional multifilament and monofilament surface longline styles used by the Spanish fleet targeting swordfish (*Xiphias gladius*) in the South East Pacific. Collect. Vol. Sci. Pap. ICCAT, 66(4): 1541-1553.

Nicholson, S.E. 1997. An analysis of the ENSO signal in the tropical Atlantic and Western Indian oceans. International Journal of Climatology, 17: 345–375.

Rey, J. C., Mejuto, J., and Iglesias, S. 1988. Evolución histórica y situación actual de la pesquería de pez espada (*Xiphias gladius*). Collect Vol. Sci. Pap. ICCAT, 27: 202-213.

Robson, D. S. 1966. Estimation of relative fishing power of individual ships. Res. Bull. Int. Comm. N.W. Atl. Fish, 3: 5-14.

Venegas, S.A., Mysak, L.A. and Straub, D.N. 1997. Atmosphere–Ocean coupled variability in the South Atlantic. Journal of Climate, 10: 2904-2920.

Table 1. Summary of ANOVAs for each CPUE analysis, in number (upper) and in biomass (lower).

South Atl. Spain.LL SWO, CPUE in number of fish
Dependent variable: log (CPUEn)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	1867.274181	35.231588	221.76	<.0001
Error	6262	994.866119	0.158874		
Corrected Total	6315	2862.140300			

R-Square	Coeff Var	Root MSE	cpue1 Mean
0.652405	18.70289	0.398589	2.131165

Source	DF	Type III SS	Mean Square	F Value	Pr > F
cyr	22	52.3058434	2.3775383	14.96	<.0001
qtr	3	5.0319064	1.6773021	10.56	<.0001
area	4	12.0543289	3.0135822	18.97	<.0001
gear	1	147.7933471	147.7933471	930.26	<.0001
bait	2	1.8358268	0.9179134	5.78	0.0031
ratio	9	872.2294400	96.9143822	610.01	<.0001
qtr*area	12	17.4656868	1.4554739	9.16	<.0001

South Atl. Spain.LL SWO, CPUE in weight
Dependent variable: log (CPUEw)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	2206.751886	41.636828	284.06	<.0001
Error	6262	917.868784	0.146578		
Corrected Total	6315	3124.620670			

R-Square	Coeff Var	Root MSE	cpue1 Mean
0.706246	6.35853	0.382855	6.021117

Source	DF	Type III SS	Mean Square	F Value	Pr > F
cyr	22	45.694868	2.077039	14.17	<.0001
qtr	3	6.701864	2.233955	15.24	<.0001
area	4	67.265038	16.816259	114.73	<.0001
gear	1	136.852775	136.852775	933.65	<.0001
bait	2	1.039670	0.519835	3.55	0.0289
ratio	9	1025.551715	113.950191	777.41	<.0001
qtr*area	12	16.891541	1.407628	9.6	<.0001

Table 2. Estimated parameters (lsmean), standard error (stderr), CV%, relative CPUE in number (CPUEn) and in biomass (CPUEw) of swordfish and upper and lower 95% confidence limits for the Spanish longline fleet in the South Atlantic during the period analyzed 1989-2011.

Year	Lsmean	Stderr.	CV%	UcpueN	Mean CPUEN	LcpueN
1989	2.261	0.054	2.404	10.689	9.609	8.638
1990	1.942	0.038	1.962	7.522	6.981	6.478
1991	1.949	0.035	1.805	7.526	7.024	6.556
1992	1.857	0.032	1.710	6.820	6.408	6.022
1993	1.761	0.027	1.524	6.134	5.820	5.522
1994	1.955	0.028	1.416	7.462	7.068	6.695
1995	2.121	0.027	1.287	8.805	8.346	7.911
1996	2.001	0.026	1.305	7.789	7.400	7.031
1997	1.949	0.023	1.172	7.342	7.020	6.713
1998	1.942	0.025	1.297	7.328	6.975	6.639
1999	1.969	0.026	1.330	7.540	7.163	6.805
2000	2.169	0.028	1.292	9.244	8.750	8.282
2001	2.011	0.024	1.202	7.834	7.472	7.126
2002	1.955	0.025	1.276	7.418	7.064	6.727
2003	1.863	0.027	1.449	6.797	6.445	6.112
2004	1.897	0.034	1.792	7.135	6.669	6.232
2005	2.066	0.033	1.612	8.429	7.896	7.397
2006	2.066	0.033	1.575	8.421	7.900	7.412
2007	2.025	0.033	1.645	8.090	7.579	7.100
2008	1.966	0.030	1.529	7.582	7.148	6.739
2009	2.050	0.029	1.401	8.219	7.769	7.344
2010	2.061	0.030	1.459	8.334	7.857	7.408
2011	2.021	0.029	1.447	8.000	7.551	7.130

Year	Lsmean	Stderr.	CV%	UcpueW	Mean CPUEW	LcpueW
1989	6.285	0.052	0.831	595.227	537.329	485.063
1990	6.000	0.037	0.610	433.879	403.852	375.904
1991	5.966	0.034	0.566	416.953	390.237	365.233
1992	5.874	0.031	0.519	377.664	355.743	335.095
1993	5.735	0.026	0.449	325.602	309.565	294.318
1994	5.869	0.027	0.453	373.127	354.182	336.199
1995	6.001	0.026	0.437	425.322	404.010	383.766
1996	5.900	0.025	0.425	383.618	365.211	347.687
1997	5.830	0.022	0.376	355.387	340.426	326.094
1998	5.805	0.024	0.417	348.297	332.163	316.777
1999	5.875	0.025	0.428	374.135	356.136	339.004
2000	6.063	0.027	0.444	452.919	429.642	407.561
2001	5.941	0.023	0.391	398.107	380.394	363.468
2002	5.896	0.024	0.406	380.993	363.512	346.833
2003	5.767	0.026	0.452	336.296	319.563	303.662
2004	5.756	0.033	0.576	337.431	316.196	296.297
2005	5.940	0.032	0.539	404.636	380.045	356.949
2006	5.950	0.031	0.525	408.063	383.810	360.999
2007	5.912	0.032	0.541	393.358	369.448	346.992
2008	5.876	0.029	0.491	377.414	356.645	337.019
2009	5.962	0.028	0.462	410.294	388.708	368.256
2010	5.939	0.029	0.486	401.872	379.756	358.856
2011	5.908	0.028	0.475	388.960	368.127	348.409

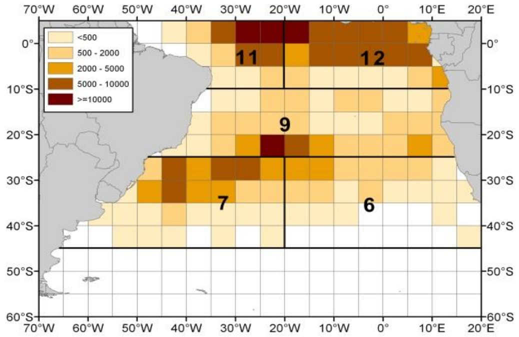

Figure 1. Geographical distribution of the nominal fishing effort (in thousands of hooks) used for the CPUE standardization of the Spanish surface longline fleet in the South Atlantic, during the whole period 1989-2011 and area definition used for the GLM runs.

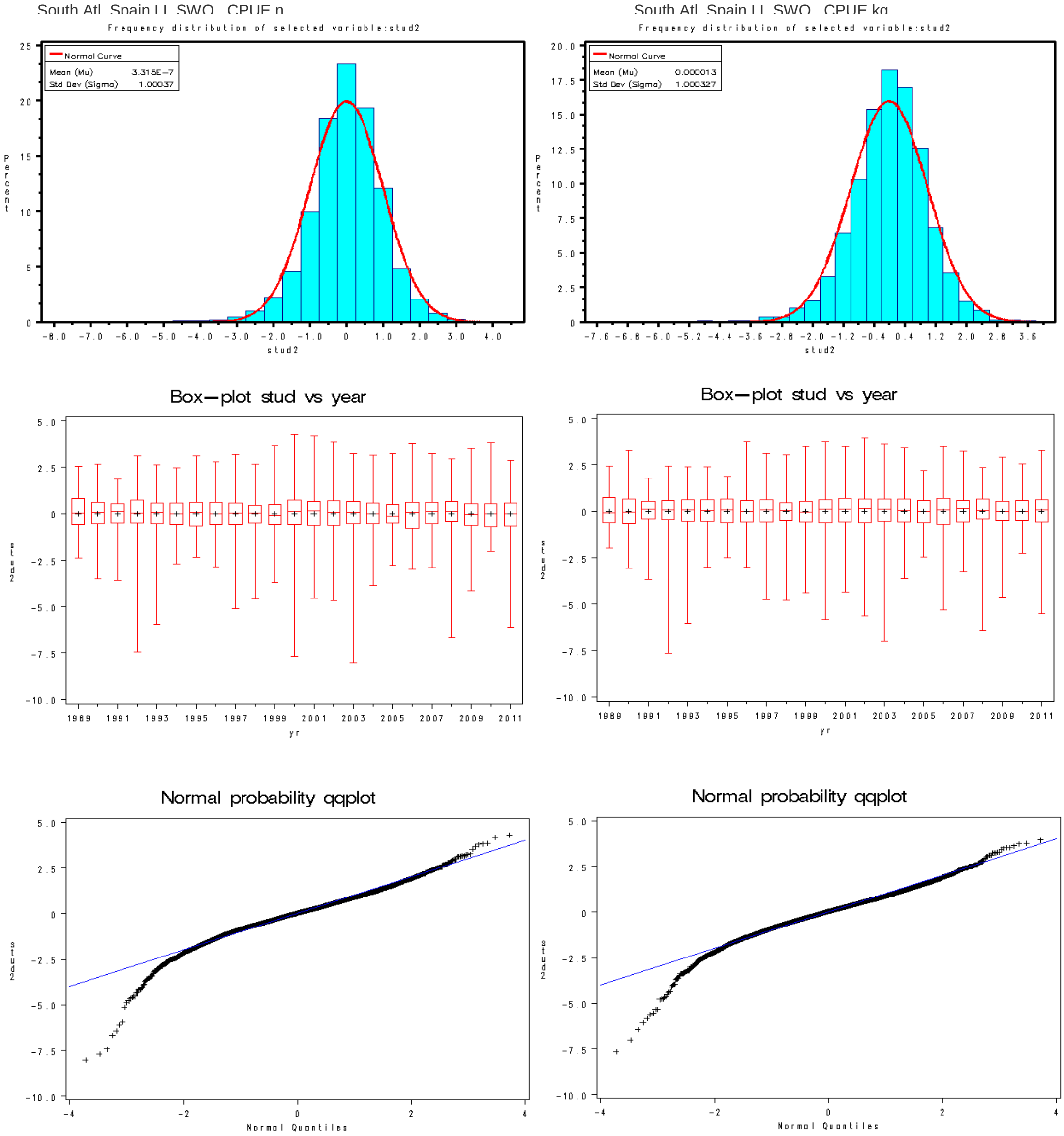

Figure 2. Diagnosis of the GLM runs for standardized CPUE in number (left) and the CPUE in biomass (right) of swordfish in the South Atlantic: Frequency distribution of the standardized residuals, years combined, and normal fit (upper). Variability box-plot of the standardized residuals by year (medium) and normal probability qq-plot (lower).

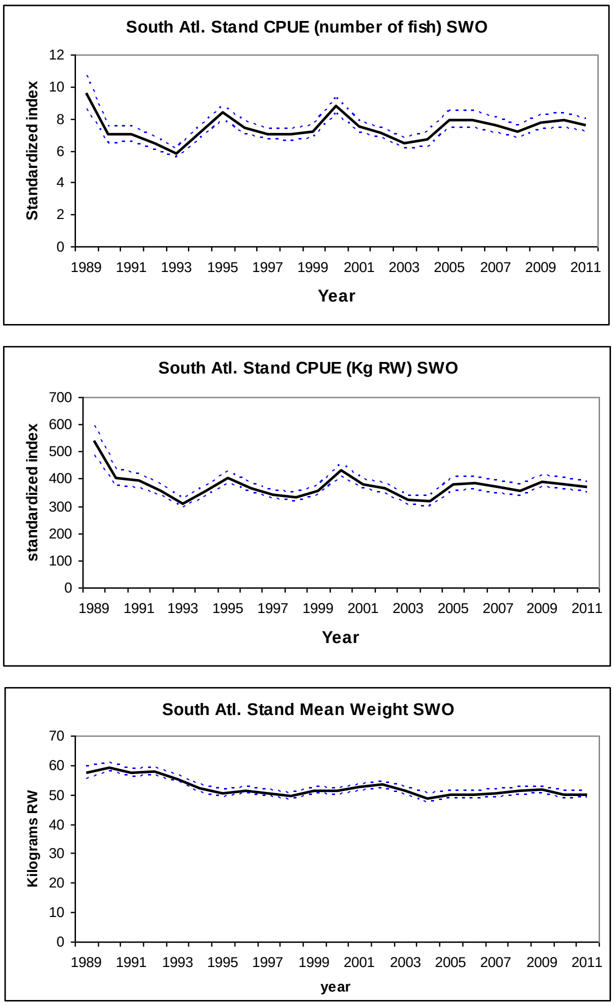

Figure 3. Standardized CPUEs per thousand hooks, in number of fish (upper), in kilograms round weight (medium) and standardized mean round weight in kilograms (lower) for swordfish observed in the Spanish surface longline fleet during the period analyzed 1989-2011 in the South Atlantic.

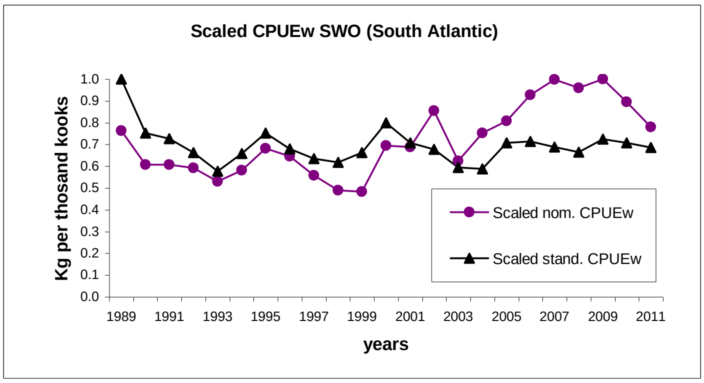

Figure 4. Scaled nominal and standardized CPUE per thousand hooks of swordfish, in kilograms round weight, in the South Atlantic for the period 1989-2011. Both series are scaled from their respective maximum.